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SUPWIND Deliverable D 5.2

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Report describing the database developed in Working Package 5

Database for model analysis within the SUPWIND project – Main sources and assumptions

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1 Introduction

This report is part of the research project SUPWIND (Decision Support for Large Scale Integration of Wind Power), which is supported by the European Commission under the Sixth Framework Programme (Contract No. TREN/05/FP6EN/S07.61830/020158 SUPWIND) and summarises work conducted within Work Package 5.

The key objective of this work package was to update, improve and extend the input database developed within the Wilmar project. We describe data requirements of specific models applied in the SUPWIND project and then address specific data issues. We list major data sources and explain approaches for the preparation of input data.

The report is structured as follows: After providing a brief description of the project in Section 1 we shortly describe the models applied in the SUPWIND project including their data requirements in Section 2. Section 3 contains information on the database on conventional power plants which was extended and updated in the course of the project. Section 4 summarises potentials and cost of renewable technologies for electricity generation used for simulating RES-E scenarios. Sources for wind speed and wind power time series are addressed in section 5. The report concludes with a description of other data required for the models like load data, hydro data and data for reflecting a detailed CHP operation in Section 6.

1.1 Project description

The SUPWIND project was launched in October 2006 with an overall project duration of 36 months. The key objective of the project is to demonstrate the applicability of decision support tools based on stochastic analysis and programming for operational management of grids and power plants. Besides, the applicability of strategic analysis tools for decision support for long-term management of grids will be demonstrated and a detailed analysis of improved coordination mechanisms between grid operators, power plant operators, power exchanges etc. will be performed.

More specifically the evaluation of regional and trans-national transmission line investments caused by large scale introduction of wind power will be analysed in detail. However the strategic issues at hand can only be addressed adequately if a good understanding of the operational management of grids with high wind energy penetration is achieved. Therefore the project simultaneously aims at demonstrating the applicability of tools for the operational management of grids and power plants under large scale wind power generation and corresponding tools for strategic analysis. In the operational management the inclusion and use of online wind-power data is a particular focus. By also including load uncertainty and stochastic outages, the operational tools will be able to estimate the need for power reserves in the system as a function of the precision of the wind power forecast and load forecast and the probability of outages. This will enable transmission system operators responsible for securing power reserves to optimise the reservation of power reserves and correspondingly minimise the costs connected to the reservation of power reserves.

In order to achieve the objectives of the project, two phases comprising a total of nine work packages are foreseen. Phase I covers the first 18 months of the project duration and is completed, when the key research activities, being WP 2 and WP 3, are completed. Phase II is entirely devoted to the application of the developed extended tools in several case studies. The work package structure is as follows:

WP1 covers the general project management activities.

WP2 and 3 are key research activities, since the tools necessary to achieve the objectives of the project are developed there. In WP2 the functionality of the Wilmar Planning Tool is extended to include evaluation of transmission line and power plant investments. WP3 extends the Wilmar Planning Tool to include load uncertainty and stochastic outages in the stochastic optimisation.

As part of the demonstration of the applicability of the tools, the input data to these decision support tools has to be collected. This includes data for the existing power systems in the EU and scenarios for the development of the power systems in the future. WP4 takes care of the scenario generation, and WP5 addresses the collection of data for the present power systems.

WP4 develops possible overall scenarios on the future of the European electricity market. First, the work package aims at identifying overall scenarios on the future of the European electricity market, being embedded in the development of the European and World economy and based on scenarios already in use in the EU policy advisory process. Furthermore, existing scenarios are synthesized and own scenarios are built based on those. Using the inventory of European scenarios and the perspective on large scale integration of wind power, key parameters are identified which describe major elements for the future electricity system development. Thereby interdependencies between the different parameters are first discussed qualitatively, and then a set of exogenous parameters is selected – whereas other parameters may be endogenously determined in the strategic model. Finally, a limited number of scenarios is extracted, which reflect possible evolutions of the power systems in the future. Thereby some contrasting developments will be retained to illustrate the impact of political decisions on the integration of wind energy and to enable the system operators to identify robust decisions when using the strategic planning tool in WP6.

WP5 extends the databases constructed in the WILMAR and GreenNet/GreenNet-EU27 projects to cover EU27 except Cyprus and Malta but including Norway and Switzerland. Furthermore the data needed to analyse more specific operational cases, such as the operation of the Nordel system in a situation with large scale installation of onshore and offshore wind power in the Nordic countries, will be collected in close corporation with the relevant TSO.

In WP6 the European Power System scenarios developed in WP4 are analysed with the strategic planning tool complemented with input from the analysis of selected operational cases. The scenarios will focus on large scale deployment of wind power and the resulting need and costs of investments in transmission lines and new flexible generation facilities including storages. Covering EU27, the tool will enable analysis of the bottlenecks arising in the European power system as a result of the location of wind power in high wind resource areas being in some cases remotely situated relatively to the high consumption centres.

In WP7 selected operational cases will be analysed in close corporation between model developers and TSOs. Each case will be evaluated with regard to the usefulness of the operational tool in helping with the day to day planning especially the estimate of the need for power reserves. The specific issues related to inclusion of online power system data in the operational tool will be analysed for each case. Furthermore the ability of the operational tool in testing the robustness of the power system towards extreme events will be evaluated.

WP8 will analyse changes in the market design for day-ahead and regulating power markets and use the tools developed in WP2 and WP3 to see how much this influences the feasibility and costs of wind power integration.

These WPs are complemented by WPs devoted to internal and external communication issues, notably project management (WP1) and dissemination (WP9).

Figure 1 shows a graphical presentation of the work packages.

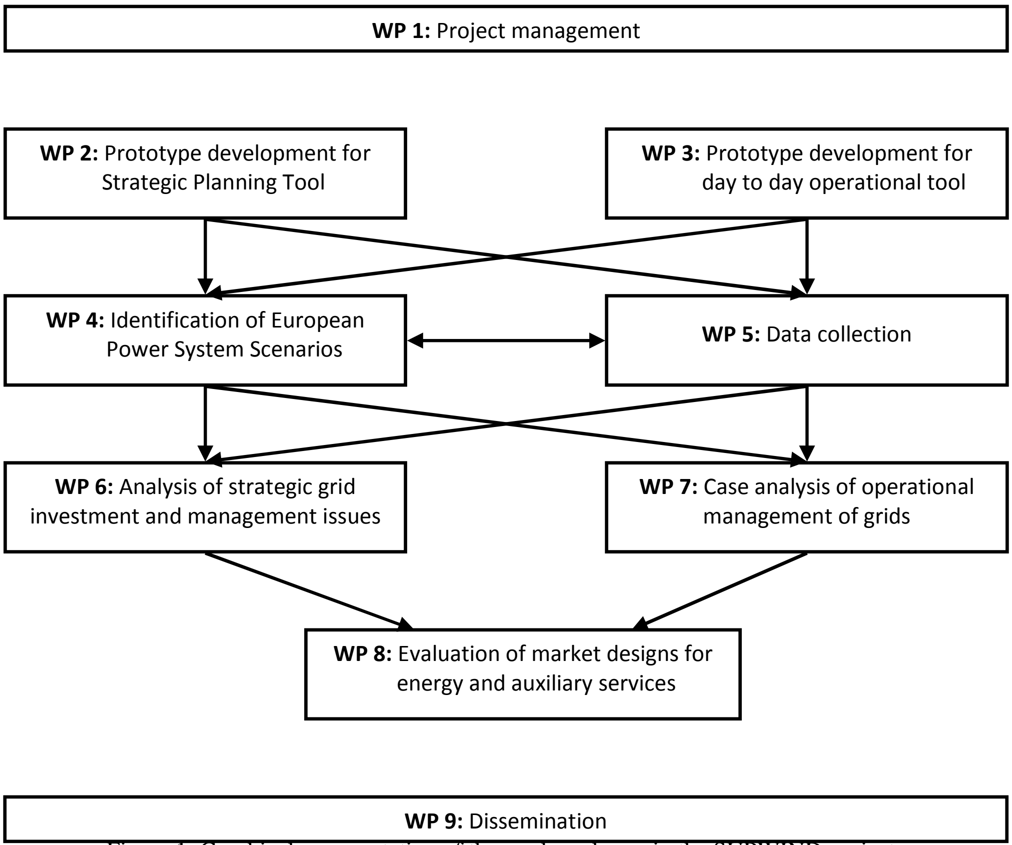

Figure 1. Graphical representation of the work packages in the SUPWIND project.

2 Background information

2.1 Overview on models applied in SUPWIND project

Data requirements are defined by models applied within the project. In the following these models are shortly characterized.

European Electricity Market Model (E2M2s)

The stochastic European Electricity Market Model (E2M2s) is a strategic planning tool to analyse long-term scenarios of the European electricity market. It explicitly focuses on the impact of fluctuations in renewable energy generation like wind power production on the structure and operation of electricity systems with thermal and hydro power plants. In order to cope with longer time horizons, investments in new conventional power plants are treated endogenously. The fundamental approach of the model is based on a cost minimization both considering the operation and extension of the existing European power system. Operational details of the unit commitment like start-up costs or lower part-load efficiency of thermal power plants, the use of storages as well as transmission constraints between countries have an important effect on the pricing of wholesale electricity and are consequently treated within the model. The transmission grid can either be represented in form of transmission constraints between markets (NTC values) or be approximated by a DC load flow model. Modelling is done with a rather high and flexible time resolution, encompassing currently 12 typical days per year and 12 time segments per day. In addition especially the characteristics of the stochastic fluctuations of renewable energy production are taken into account by application of a stochastic approach with recombining trees. Thereby both the stochasticity of wind and hydro production are modelled explicitly.

Required key input data includes

- existing capacities for conventional power plants, renewables and storage,
- specific investment cost of conventional technologies
- fuel & CO2-prices,
- power plant parameters (efficiencies, availability, start-up costs),
- grid parameters (NTC or PTDF),
- load data and
- RES-E availability (wind power time series, hydro inflow data, etc.)

Joint Market Model (JMM) and Scheduling Model (SM)

The Joint Market Model (JMM) analyses power markets based on an hourly description of generation, transmission and demand. The model is multi-regional consisting of regions connected by transmission lines. It takes into account the balance between supply including net export and demand in each region, capacity restrictions for production units and transmission lines, technical restrictions for power plants including

CHP, heat storages, electricity storages (pumped hydro) and hydro reservoirs. The transmission grid can either be represented in form of transmission constraints between markets (NTC values) or be approximated by a DC load flow model. The JMM derives hourly electricity market prices from short term marginal system operation costs. This is done on the basis of an optimisation of the unit commitment and dispatch taking into account the trading activities of the different actors on the considered energy markets. The model is defined as a stochastic linear programming model. The stochastic part is represented by a scenario tree for possible wind power generation forecasts, electricity demand forecasts and demand for tertiary reserves for the individual hours. The JMM uses an exogenously specified portfolio of power plants, transmission lines and storages. It can interact with E2M2s by receiving a power system portfolio calculated by E2M2s.

The SM is equal to the JMM except that unit commitment is done with integer variables making the model a mixed integer, stochastic (or deterministic) programming model. The SM is used for analysing smaller model areas (e.g. one market area or one synchronous area) with a detailed representation of power plants. The JMM is used to provide boundary conditions for the smaller model areas treated with the SM. The boundary conditions can be transmission exchange schedules and/or price interfaces calculated with the JMM.

Required input data includes

- existing (and future) capacities for conventional power plants, renewables and storage,
- fuel & CO2-prices,
- power plant parameters (efficiencies, availability, start-up costs),
- grid parameters (NTC or PTDF),
- load data and
- stochastic inputs (demand for tertiary reserves, scenario trees for wind and load forecasts, time series of power plant outages)

Scenario Tree Tool (STT)

The Scenario Tree Tool (STT) generates scenario trees containing three stochastic inputs to the Joint Market Model and Scheduling Model: the demand for positive reserves with activation times longer than 15 minutes and for forecast horizons from 15 minutes to 36 hours ahead (in the following named tertiary reserves) as well as forecasts of wind power production and of load. The determination of the tertiary reserve demand by the Scenario Tree Tool allows quantifying the effect forecast errors have on the tertiary reserve requirements for different forecast horizons. Furthermore the Scenario Tree Tool generates time-series describing forced outages of conventional power plants.

Required input data includes

- wind power and load time series with hourly resolution,
- forecast errors depending on the forecast horizon,
- correlation between forecast errors in different geographic regions,

- data describing power plant outages on level of individual units (scheduled outages, forced outage rate, mean time to repair) and
- capacity of individual power plants

GreenNet-Europe

The GreenNet-Europe model simulates least cost scenarios for the future deployment of renewable electricity technologies (RES-E) based on underlying support and integration policies. Investment decisions are modelled on a yearly basis under the assumption of myopic expectations. The Economic assessment takes into account long run marginal cost (LRMC) of disaggregated RES-E potentials, exogenously given power prices and specific support conditions. Most common schemes for supporting RES-E like feed-in tariffs, quota systems with tradable green certificates, tendering schemes and investments subsidies are implemented in the model. Grid and system integration cost components (grid connection, grid reinforcement, balancing, system capacity) are reflected in the LRMC of wind power depending on the corresponding cost allocation policy. RES-E technologies are described in form of disaggregated dynamic cost-resource curves that result from a static description of future potentials and corresponding cost taking into account dynamic aspects like technological learning and diverse deployment barriers and constraints (industrial, technical, market, administrative, societal). Exogenous power prices calculated with E2M2s can be used as an input for the GreenNet-Europe model. In turn scenarios for the RES-E capacity deployment serve as an input for E2M2s.

Required key input data on country level include

- disaggregated potentials and cost of RES-E technologies,
- yearly average base load price,
- yearly gross demand,
- type and key specification of RES-E support scheme (e.g. feed-in tariff and support duration)

The following graph illustrates how described models are operated and interlinked with databases. The GreenNet-Europe model is not linked to this database structure but operates with an independent database.

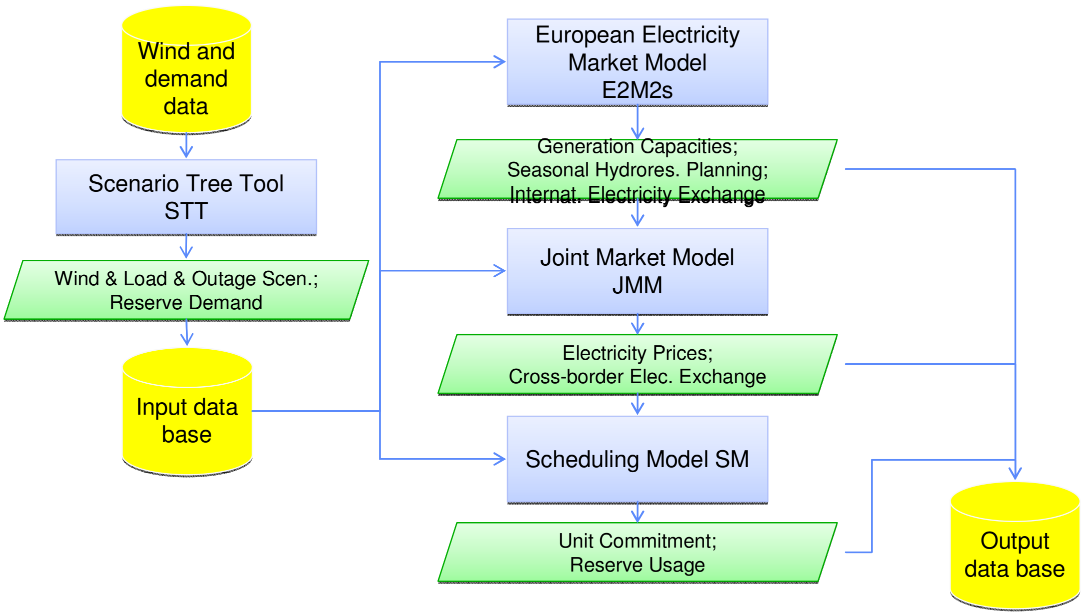

Figure 2. Overview of SUPWIND Planning Environment

2.2 Data structure

The data structure of the input database has been defined within the WILMAR project and further developed within the SUPWIND project inline with model improvements and extensions. A detailed description of the original WILMAR database is given in Kiviluoma and Meibom (2006). Within the SUPWIND project the E2M2s was coupled to the WILMAR database structure meaning that now all market models use a consistent set of input data.

Main model extensions include the introduction of load uncertainty and the implementation of forced outages on power plant level in the JMM and SM. Corresponding input data is generated using the STT which has been extended by this features as described in the WP3 report (cf. Kristoffersen et al. (2008)). Both the JMM and the E2M2s have been extended by a DC load flow model in order to improve the consistency of market results with physical grid operation. A detailed description of extensions and improvements is provided in the WP2 report of this project (cf. Weber et al. (2008)).

2.3 Geographical coverage

The database developed with the WILMAR project covered the Scandinavian countries as well as Germany. Within the SUPWIND project this database has been extended to remaining EU Member States (excluding Cyprus and Malta) including Norway and Switzerland. While for analysis on EU-level performed within WP6 the geographic resolution is on country level, for case study analyses the respective countries are subdivided in a number of regions in order to represent internal power flows in the required detail. Methodologies for the geographical disaggregation of data and additional input data requirements are described in the corresponding work package reports (WP6 and WP7).

3 Database on conventional power plants

Data on conventional power plants constitute a key input parameter for the E2M2s, the JMM and the SM. The database covers information on power plant level (actually unit level) which might be further aggregated depending on specific input data needs of market models and the level of detail required for analyzing specific aspects of large-scale wind power integration.

3.1 Major data sources

The current version of the database on conventional power plants is based on the WILMAR database and results from the integration of a number of data sources, which are shortly characterized in the following indicating extracted information.

UDI World Electric Power Plant database (WEPP), European edition

- Contains comprehensive data on power plant level (up to 41 parameters per unit)
- Covers all European countries
- Extracted information includes name of unit, location, status, year of commissioning, nominal capacity and fuel types

VGE database – Europäische Energie- und Rohstoffwirtschaft 2007

- Data on power plant level for units > 100MW
- Covers 28 European countries
- Extracted information includes
  - hydro power types (run of river, reservoir, pumped storage)
  - fuel type for coal units (lignite vs. coal)
  - type of thermal units (steam, gas turbine, CHP)

IEA electricity information 2007

- Contains comprehensive statistical data for the power and heat sector up to the year 2005
- Covers OECD countries
- Information of installed capacities per fuel type used to determine dummy capacities for OECD countries

EURPROG statistics 2005

- Contains comprehensive statistical data for the power sector up to the year 2003 and prospects up to 2020
- Covers 29 European countries
- Information of installed capacities per fuel type used to determine dummy capacities for non OECD countries

Internet research for large units (>50MW)

- Information on CHP type (backpressure, extraction condensing)
- Information on hydro type (run of river, reservoir, pumped storage)

– Technological data for specifying default technologies

In the course of the application of the set of SUPWIND tools within the European Wind Integration Study (EWIS) further efforts have been undertaken to improve data quality. For most of covered countries Transmission System operators have crosschecked data on conventional power plants.

3.2 Approach for generating input data

In a first step the Wilmar database was extended using information from the WEPP and VGE database as well as other information available in the Internet and from statistical sources. The resulting database contains key information on power plant level and covers all 27 analysed countries. We then compare capacities of power plant data with statistical information on the level of fuel types. Deviations are taken into account in form of so called dummy power plants for which a typical technology specific rated power is assumed. Technological power plant parameters like efficiencies, operation constraints and specific emissions are in general not available for single units. We therefore specify these parameters for so called default technologies that are characterized by the decade of commissioning, the unit type (we distinguish between 11 main types) and used fuel and allocate each single unit to the corresponding default technology. A first set of technological data for default technologies was available in the Wilmar database and has been updated within the SUPWIND project. Finally data on power plant level is aggregated to so called unit groups depending on the scope of analysis and is then used as an input for the corresponding market models. Figure 3 below illustrates the approach for generating input data on conventional power plants.

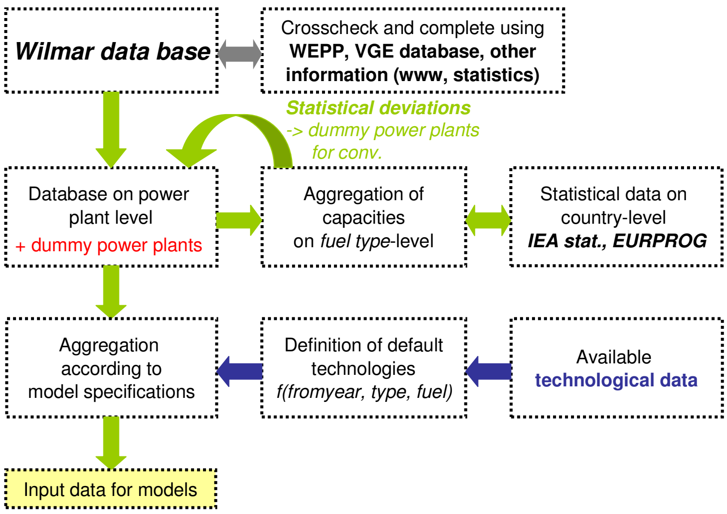

Figure 3. Approach for generating input data on conventional power plants

3.3 Representation of conventional power plants

To allow for a realistic representation of power plant operation being crucial for wind integration analyses, conventional power plants are specified by a number of parameters as summarized in the following tables. Key parameters indicated in Table 1 are available on power plant level while technological parameters listed in Table 2 are in general specified for default technologies as described above. For a detailed description of technology data see Kiviluoma and Meibom (2006).

Table 1. Key technology data specified on power plant level

Parameter	Definition (and parameter name in the market models)
Comments	Additional information about the unit.
Source	Data source
Country	Country where the unit is located.
City	Name of the city that the unit is situated in or near by.
DHgrid	Name of the district heating grid that the unit delivers heat to.
Node	The name of the PSSE (grid) node that the unit is allocated to
GenID	The identification string of PSSE (grid) generator that the unit is allocated to
DefTech	The default technology that the unit inherit data from in case of missing data for the unit
Type	Technology type. A technology type is described by a specific set of equations in the optimisation model.
SubType	Possibility to divide the type into sub groups. Used to distinguish onshore and offshore wind power
FromYear	First operational year of the unit, or for future units an indication of when the technology is available. –GDFROMYEAR
EndYear	The last operational year of the unit.
Fuel	Main fuel used. –GDFUEL
MaxPower	Max output production [MW]. Only electricity output for backpressure and extraction. –GKFX
MinPower	Minimum output production when online [MW]. Only electricity output for backpressure and extraction. Used to calculate GD_MIN_LOADFACTOR=MinPower/MaxPower
CHP_MaxHeat	Max heat production [MW]. Only applies for backpressure and extraction.
Sto_MaxContent	The maximum energy capacity of the storage [MWh]. Only relevant for storages and hydro reservoirs. –GDMAXCONTENTFACTOR
Sto_MinContent	The minimum energy capacity of the storage [MWh]. Only relevant for storages and hydro reservoirs. –GDMINCONTENTFACTOR
Sto_MaxCharging	The capacity for the charging process of storages (pumping process of pumped hydro storage) [MW]. –GDMAXSTOLOADFACTOR

Table 2. Technology data specified for default technologies

Parameter	Definition (and parameter name in the market models)
AvgEff	Net average output efficiency [MWhOut/MWhFuel]. Only to be specified if data for MaxEfff and PartEff do not exist. –GDFE
MaxEff	Net output efficiency at maximum electricity output for electricity producing units and maximum heat output for units producing only heat [MWhOut/MWhFuel].
PartEff	Net output efficiency at minimum electricity output for electricity producing units and minimum heat output for units producing only heat [MWhOut/MWhFuel].
CHP_CB	Back pressure constant. Minimum power production at maximum heat production. [MWElec/MWHeat]. Applies only for backpressure and extraction. –GDCB

Ext_CV	CV-value, Isofuel line. Decrease in electricity generation through increased heat generation [MWElec/MWHeat]. Applies only for extraction type of units. –GDCV
Reliab	Average available capacity due to technical breakdown, i.e. the reliability of the unit [ratio]. –part of GKDERATE
RampRate	Maximum ramp rate per hour [MWh/h]. –GDRAMP
MinOperTime	Minimum operation time [hours]. –GDMINOPERATION
MinDownTime	Minimum shut down time [hours]. –GDMINSHUTDOWN
LeadTime	The number of hours it takes between deciding to put a unit online and start of the production from the unit [h].
DeSO2	The degree of desulphoring, i.e. how much SO2 is removed from the flue gas [ratio]. –GDDESO2
NOX	The amount of NOx in the flue gas [mg/MJFuel]. –GDNOX
CH4	The amount of CH4 in the flue gas [mg/MJFuel]. –GDCH4
InvestCosts	Investment cost specified relatively to the capacity MaxPower [M€/MW]. Value should be discounted into Euro 2005 currency –GDINVCOST
VarOaMcosts	Variable operating and maintenance costs specified relatively to the total useful energy output [€/MWh]. Value should be discounted into Euro 2002 currency –GDOMVCOST
AnnualOaMcosts	Annual operating and maintenance costs specified relatively to the capacity MaxPower [k€/MW]. Value should be discounted into Euro 2002 currency. –GDOMFCOST
StartUpFuelType	The type of fuel used to start up the plant
StartUpFuelCons	Start-up fuel consumption. MWh fuel used to increase the capacity online by one MW [MWh/MW]. –GDSTARTUPFUEL
StartUpVarCosts	Other variable start-up costs than fuel costs [€/MW]. Value should be discounted into Euro 2002 currency. –GDSTARTUPCOST
Sto_LoadLoss	The effiency of storage when loading [Energy stored/Energy input]. –GDLOADLOSS

4 Potentials and cost of wind power and other RES-E technologies

Scenarios for the future development of Renewable energy sources for electricity production (RES-E) in general and wind power in special are derived with the GreenNet-Europe model. A core input parameter for this model is information on potentials and corresponding cost for diverse RES-E technologies on country level. In the following we provide background on potential definitions and summarise the current status of the database indicating both figures on country and technology level.

4.1 Future potentials in analysed countries

Future RES-E potentials indicated in this chapter do not represent policy targets nor expected figures for the year 2020. The additional mid-term potential should instead be interpreted as the maximal additional potential that might be achieved when all existing barriers can be overcome and all driving forces are active. Depending on support policies and barrier settings applied in the simulations the utilised additional RES-E potential for the year 2020 may be considerably lower.

Figure 4 and Figure 5 depict the achieved and additional mid-term potential for RES-E technologies in analysed countries on country and technology level respectively. The already achieved potential for RES-E generation in all countries equals 670 TWh[1], whereas the additional realisable potential up to 2020 is 1190 TWh. Both achieved and future RES-E potentials are distributed heterogeneously amongst investigated countries. France, Germany, Norway, Spain and UK show the highest absolute numbers and represent about 60% of the additional potential within analysed countries.

While for established technologies like hydro power and geothermal electricity additional potentials are minor compared to the existing utilisation, considerable potentials are identified for new RES-E technologies. With 569 TWh wind power shows the highest additional potential which is equally shared between onshore and offshore utilisation. The additional potential up to 2020 for electricity from biomass in terms of solid resources and biogas amounts to 314 TWh. Further promising RES-E options include tide and wave energy, PV and solar electricity. The composition of the additional mid-term potential in investigated countries is heterogeneous as illustrated in Figure 6.

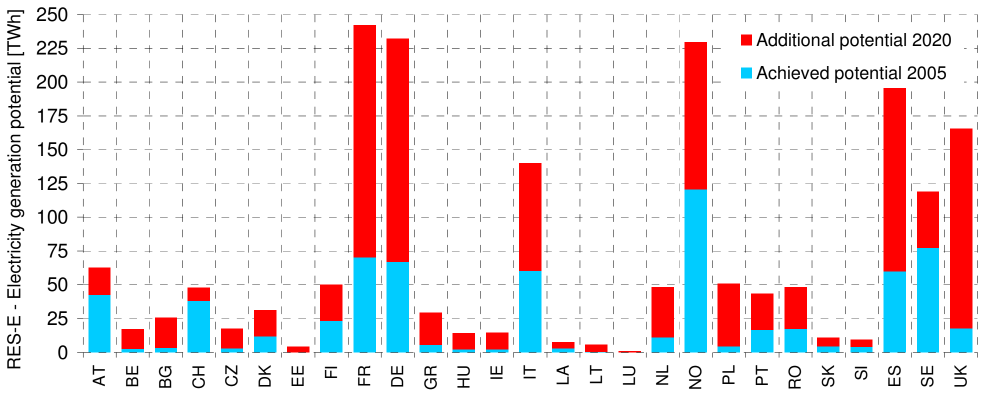

Figure 4. Achieved (2005) and additional mid-term potential (2020) for electricity from RES on country-level

[1] The electricity generation potential represents the output potential of all plants installed up to the end of each year. The figures for actual generation and generation potential differ in most cases – due to the fact that, in contrast to the actual data, the potential figures represent normal conditions (e.g. in case of hydropower, the normal hydrological conditions), and furthermore, not all plants are installed at the beginning of each year.

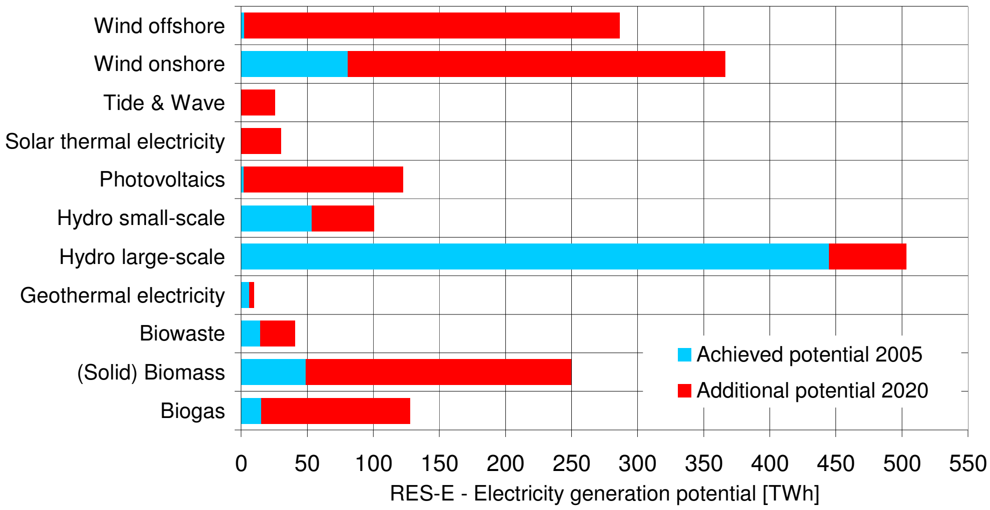

Figure 5. Achieved (2005) and additional mid-term potential (2020) for electricity from RES in analysed countries on technology-level

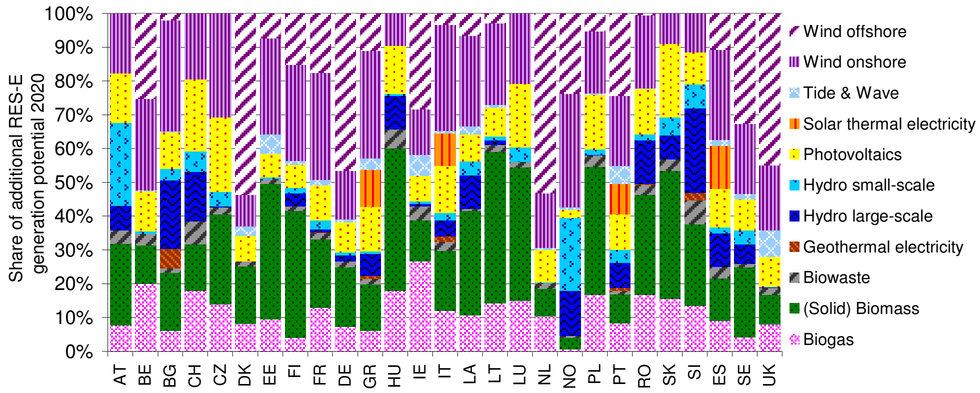

Figure 6. RES-E as a share of the total additional realisable potential in 2020 on country level

4.2 Economic data

High investment cost (and low fuel and O&M cost) of almost all RES-E technologies have been an impediment for broad market penetration. In recent years, investment cost decreased substantially for many RES-E technologies. Main drivers for cost reductions have been research and development as well as economies of scale. Also interest rates have been decreasing over the past two decades.

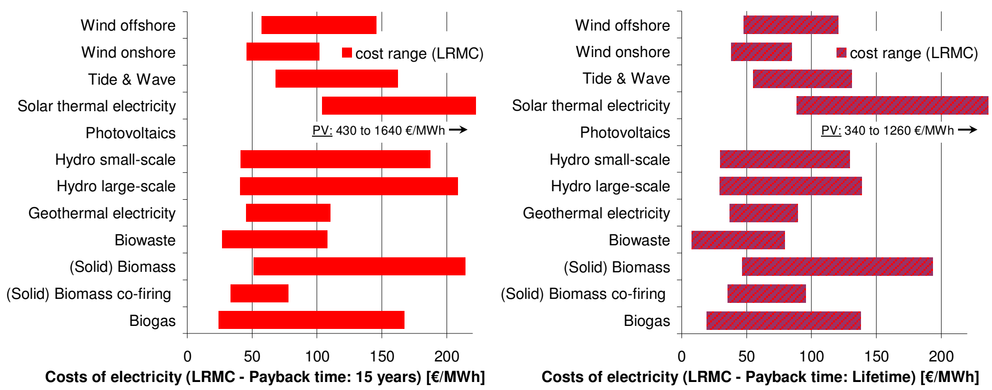

Figure 7. Bandwidth of long-run marginal generation cost (for the year 2005) of different RES-E technologies for several countries covered – based on a default payback time of 15 years (left) and payback time equal to lifetime (right).

Figure 7 depicts long-run marginal generation cost[2] by RES-E technology. Two different settings are applied for the payback time:[3] On the one hand, a default setting of 15 years for all RES-E options (left)[4], on the other hand, the payback is set equal to the RES-E technology-specific life time (right). The broad range of cost for several RES-E technologies represents resource-specific conditions in different regions (countries). Costs also depend on technological options available (e.g. compare co-firing and small-scale CHP plants for biomass).

5 Wind speed and power time series

Wind power time series with an hourly time resolution serve as an input for the Scenario Tree Tool. For some of the investigated countries (Austria, Denmark, Germany, Ireland, Spain) measured wind power time series are available for recent years. For others modelled wind power time series developed within the TradeWind project are used.

5.1 Measured wind power data

The following table gives an overview on measured wind power time series collected within the SUPWIND project.

Table 3. Overview on available measured wind power time series

Country	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**
Austria					X	X	
Denmark	X	X	X	X	X	X	X
Germany					X	X	X
Ireland	X	X	X	X	X	X	
Spain	X	X	X	X	X	X	
Greece					X		

5.2 Modelled wind power data

Wind power time series simulated in the TradeWind project base on Reanalysis data for wind speeds with 6 hourly time resolution which cover all of Europe. Wind speeds are linearly interpolated to derive hourly values. In order to also reflect intra-day variability accordingly a stochastic component is added which is calibrated taking into account the

[2] Long-run marginal generation cost is the relevant indicator for investment decisions.
[3] For both cases an interest rate of 6.5% is used.
[4] A payback time of 15 years aims to reflect the investor's point-of-view in competitive, liberalised markets.

power spectral density of measured data. Wind speeds are adjusted for hub heights and wind shear exponents depending on the local terrain. For the translation of wind speeds into wind power equivalent wind power curves are used. These power curves result from empirical analyses and reflect effects like spatial smoothing, array losses, electrical losses and availability. In the case of significant deviations between wind power capacity factors of simulated and measured data wind speeds are further adjusted. Finally power curves are scaled with installed capacities allocated to Reanalysis data grid nodes. For a detailed description of the approach see TradeWind (2009). A consistent data set is available for the years 2000 to 2006.

Even if simulated time series do not perfectly match measured data, there are also advantages especially when investigating future wind scenarios. Expected changes in geographic distribution of onshore wind and the future exploitation of offshore potentials can be reflected in simulated data. Furthermore a consistent data set for a number of years reflects varying yearly wind availability.

5.3 Data used for analysis

Measured as well as simulated wind power time series used for the model runs refer to the year 2006. For wind onshore measured data is used if available for the year 2006. For other countries we use TradeWind data. For wind offshore TradeWind time series are used for all investigated countries having offshore potentials. In order to reflect an average wind year wind speed time series for 2006 are scaled with a factor of 1.05. For selected countries scaling factors are applied in case of significant deviation between capacity factors of simulated data and figures reported in statistics.

Wind power time series are scaled to corresponding onshore and offshore capacities reflected in the two RES-E deployment scenarios described in WP4 report of this project (see Redl et al. (2008)).

6 Other input data

This chapter describes further data necessary to complete the system description including load data, hydro inflow and reservoir data, plant availability, CHP heat demand and data for the representation of transmission grids.

6.1 Load data

Load data is crucial for the market models which are used for the optimization of power plant investments and unit commitment. However, the transport of electricity is network based and exchanges are only possible in synchronous areas or between stations with adequate conversion equipment. Due to historical and geographical reasons, several synchronous areas grew within Europe. This regionalization of the electricity sector has also impacts on the collection of load data as type and definition of data published by the regional organizations differ.

In this Chapter we first provide common definitions for load related key figures. Afterwards data needs are discussed and information about the uncertainty that goes together with the usage of load data is given. Finally we explain the approach used for deriving load data for future periods.

6.1.1 Key figures of electricity demand

The most important load related key elements are the consumption and load time series. Generally, consumption is the cumulated load over a certain time period, like a month or a year. Consumption is measured in energy units (MWh or GWh). Load time series are profiles that indicate the average consumed power during a defined time period of typically one hour. In this case the load curve for a day consists of 24 hourly load values. The unit of the load values is MW or GW. The consumption (E) is a function of Power (P) and time (t):

$$E = \int P \cdot dt$$

Consumption is distinguished between net consumption and gross consumption. The definition of these two types of consumption leads to first problems when comparing the published data of different sources. The UCTE defines the national net electrical consumption as the sum of

i) the amount of electrical energy supplied by the electricity service utility to ultimate consumers of the network under consideration,

ii) the amount of net electrical energy produced or directly imported from abroad by industrial or commercial companies on the network and used directly for their own needs or to directly supply ultimate consumers,

iii) the amount of electrical energy consumed by establishments (offices, workshops, warehouses, etc.) of the electricity service utilities but excluding the electricity absorbed by the auxiliaries of the power stations, the losses in the main transformers of the power stations and that consumed for pumping and network losses. These consumptions are commonly called "consumptions of the electricity sector" or "own" consumptions (see UCTE (2008))."

Further, the UCTE defines the national electrical consumption as the national net electrical consumption plus losses (cf. UCTE (2008)). NORDEL includes the pumping energy for pumped storage power plants in its definition of gross consumption (cf. NORDEL (2006)). As a consequence, the definition of gross consumption by NORDEL does not correspond to the definition of national electrical consumption by UCTE. The different definitions and the different data sources lead to different figures for consumption. A comparison between data from BDEW, the organisation of German power and water utilities, and data published by UCTE should exemplify this. BDEW (2007), for example, estimates the electricity consumption for 2006 with 567 TWh whereas the UCTE estimates this value with 559 TWh. Possible reasons for inconsistence are a differing treatment of industrial power producers, small power plants or electricity for railway systems. Unfortunately, in most cases it is difficult to get detailed information on the components included and excluded. In electricity markets, demand has to be satisfied in real time. As a consequence, the shape of the load profile plays an important role, too. For the Continental European countries, UCTE provides hourly load time series since 2006, which cover its members. A representativeness figure, which is published in UCTE (2007) indicates what percentage of the overall system load is represented in the UCTE load time series. The load time series for Germany covers 91% of the overall system load according to UCTE. One would expect that the sum of all load time series values of one year would have the same value as the yearly consumption after a correction with the representativeness figure. This is not the case for Germany. Table 4 shows the cumulated hourly loads for UCTE countries and compares it with national electricity consumption. Even though the difference is small for other countries, the overall picture is the same. Load data by UCTE includes transmission losses, but excludes the power for pumped storage power plants.

Table 4. Comparison of UCTE load data and consumption statistics for selected countries

	Germany	Italy	Poland
Sum of hourly load values for 2006 in TWh	489.07	334.24	134.52
Correction with representativeness	537.44	334.24	134.52
Yearly national consumption in 2006	559.00	337.80	136.5
Difference in percent	3.86	1.05	1.45

For the United Kingdom, a half hourly load time series is published by the National Grid Company (NGC) (see NGC (2008)). The provided values are based on metering of generators. It is not evident how representative these figures are. The definition by NGC includes transmission losses, the power for pumped storage power plants and the exchange balance. However, the exchange balance is provided separately, too. Peak load hours often are of special interest for electricity system studies. The data for maximal peak load values that is published by ETSO (2008) is consistent with the data published by UCTE and NORDEL statistics. In winter 2006/2007, the maximal peak load for Sweden was published in both sources (ETSO and NORDEL) with 26.1 GW, for example. A comparison of peak load data by ETSO and the load time series by NGC leads to the same result. It seems that ETSO applies the data by the regional TSO organisations. However, one must be aware that the underlying definitions of the data are different.

6.1.2 Methodology of load implementation

For running the market models hourly load values are necessary. Due to the importance of load data for the model results, a data set as consistent as possible is necessary. For the UCTE member countries the hourly load series published by UCTE is the basis. However, the percentage of total system load that is represented by these figures is different for different member countries. We therefore linearly scale these values, so that the sum of hourly load values matches the national electrical consumption as published by UCTE.

This data set would include all network related losses, but exclude the consumption of pumped storage power plants, which is preferable, because the market models optimize the usage of pumped storage power plants endogenously. For the UK the exchange balance with other regions/countries is excluded from the consumption data. For the NORDEL countries data published by the power exchange NORDPOOL is used.

6.1.3 Load forecasts up to 2020

In line with scenarios developed for the European electricity market within WP4, demand projections of the European Commission for a Baseline and an Efficiency scenario are used as a reference for the future demand development (see EC (2006) and Redl et al. (2008)). In order to guarantee consistency of demand projections and statistical data used for 2006 we do not use absolute numbers quoted in EC (2006) but scale 2006 numbers with corresponding growth rates on country level. We derive hourly load data by linearly scaling 2006 numbers to resulting yearly consumption and thereby assume that the shape of the load curves remains unchanged in the future.

6.2 Hydro data

6.2.1 Introduction

Hydro power combined with storage capabilities in form of reservoirs constitutes a highly flexible source of power generation which is perfectly suited to balance wind power. Therefore especially for countries with significant shares of (flexible) hydro power a detailed representation is crucial for the reliability of wind integration analysis.

The following graph on the one hand illustrates the relevance of countries in terms of hydro power in Europe (EU-27 +2 -2) and on the other hand the relevance of hydro power within these countries. Significant hydro power capacities are found in alpine countries, Norway and Sweden. In the remaining EU-countries a hydro power share >10 % (in terms of capacity) can be observed for Romania, Portugal, Latvia and Luxembourg.

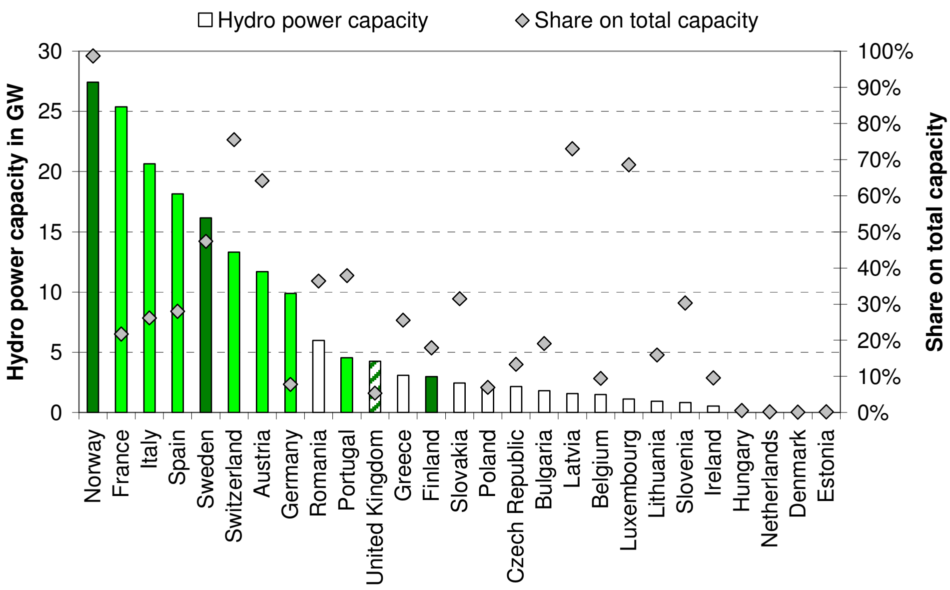

Figure 8. Hydro power in selected European countries. Sources: EURPROG (2005)

For countries marked with colours a detailed hydro representation is realised including weekly data for historic reservoir levels, historic minimum and maximum filling levels and inflows for both run of river (RoR) and hydro reservoir plants. Light green bars indicate countries covered by Markedskraft data. Striped bars indicate a still detailed hydro representation building on a less profound data basis. For other countries a simplified approach of hydro representation is applied.

6.2.2 Data sources and method of implementation

Alpine and Iberian countries

Main data sources include the Markedskraft database, UCTE monthly generation data for 2006, EURPROG installed capacities for 2003 for Spain and Portugal and national power statistics.

Markedskraft data cover Alpine countries (AT, CH, DE, FR, IT) and Iberian countries (ES, PT) and contain the following parameters on a weekly resolution:

- Reservoir filling level in %
- Total hydro production in GWh
- Total hydro inflow in GWh
- Run of River production in GWh
- Hydro storage production in GWh (only for Alpine countries)

Based on this data we determine the following input parameters for the set of SUPWIND models:

- Historic reservoir filling level: Markedskraft data
- Reservoir bounds: Minimum and maximum numbers per calendar week are derived from historic filling levels
- Total inflow: Markedskraft data

- Inflow for uncontrollable hydro power: Alpine countries: Historic run of river generation according to Markedskraft data are used; Iberian countries: Yearly run of river generation is estimated based on the installed run of river capacity (EURPROG, 2003 numbers) and assumed full load hours (4000 h/yr). The run of river generation pattern for France is scaled with estimated yearly run of river generation

Scandinavian countries

Hydro data originate from the WILMAR database and was updated with actual data provided in Nordel statistics.

Further countries with detailed hydro representation

United Kingdom

Major data sources include UK power statistics for 2006 and hydrological statistics.

It is assumed that storages in UK allow for intra-week operation only. Consequently the reservoir level (referring to the end of the week) is assumed to be constant over the whole year with 70 %. For run of river and reservoir power plants the same inflow pattern is applied. For the year 2006 the inflow pattern is derived from monthly power statistics while for the average hydrological year the pattern refers to hydrological statistics. Yearly generation is taken from national power statistics for 2006.

Greece

In order to facilitate detailed analysis of the Greek power system within work package 6 a detailed hydro power representation is necessary. Hydro power capacities are allocated to grid nodes as implemented in the JMM. Details are provided in the corresponding WP6 report.

Simplified hydro representation

Due to the lack of detailed data for the remaining countries a simplified hydro power representation is applied:

1. We assume that all hydro power generation accounts for run of river, i.e. there is no generation from hydro reservoir units in these countries. Reservoir contents are allocated to pumped storage units (PS).
2. Run of river generation patterns of neighbouring countries are scaled with yearly hydro generation excluding generation from PS (UCTE 2006 data) to derive the run of river inflow.
3. Hydro reservoir inflow and reservoir filling levels are consequently set to zero

6.3 Power plant availability

For determining the optimal unit commitment and dispatch, the possible unavailability of power plants has to be taken into account. The unavailability of a power plant can be caused by maintenances, which are of deterministic nature, or by unplanned forced outages, which are of stochastic nature. Forced outages are simulated in the STT using a Semi-Markov process. In order to also reflect unavailability due to maintenance scheduled outages are included in the Semi-Markov process. The output of this algorithm are time series of outages on power plant level which are used as an input for the SM. Data required to simulate this stochastic process include the forced outage rate (ratio between outage hours and total hours in a considered period) and the mean time to repair. These parameters are estimated per power plant class based on data provided in Meibom et al. (2007) and other sources.

6.4 Data for CHP representation

6.4.1 Introduction

Combined Heat and Power (CHP) plants show in some European countries a considerable share of the electricity production, compare Table 5.

Table 5. CHP electricity generation in EU-25 in the year 2002, based on Eurostat (2006)

Country	Total CHP electricity generation [GWh]	of which		Share of total electricity generation [%]	of which	
		Public supply [GWh]	Auto-producers [GWh]		Public supply [%]	Auto-producers [%]
EU-25	299163	163096	136067	9.9	5.4	4.5
AT	8521	3532	4990	13.6	5.6	8.0
BE	6170	4374	1797	7.5	5.3	2.2
CY	-	-	-	-	-	-
CZ	13064	9391	3673	17.1	12.3	4.8
DK	19291	16665	2625	49.1	42.4	6.7
DE	56228	33292	22936	9.8	5.8	4.0
EE	939	834	105	11.0	9.8	1.2
EL	1057	0	1057	1.9	0	1.9
ES	19316	0	19316	7.8	0	7.8
FI	28448	18000	10448	38.0	24.0	14.0
FR	22578	11470	11108	4.0	2.0	2.0
HU	4741	4336	405	21.5	19.7	1.8
IE	624	0	624	2.5	0	2.5
IT	20999	9304	11695	7.4	3.3	4.1
LT	1726	1705	21	9.7	9.6	0.1
LU	291	0	291	7.9	0	7.9
LV	1491	1450	41	37.5	36.5	1.0
MT	-	-	-	-	-	-
NL	28673	19715	8958	29.9	20.6	9.3
PL	23003	15424	7579	16.0	10.7	5.3
PT	4603	2349	2255	10.0	5.1	4.9
SE	9990	5664	4326	6.8	3.9	2.9
SI	873	564	309	5.9	3.8	2.1
SK	5659	3302	2357	17.5	10.2	7.3
UK	20877	1725	19152	5.4	0.4	5.0

The operation of CHP plants and thus their electricity generation is in general determined by the heat demand of district heating grids. Hence, the neglect of heat generation from CHP plants may result in an inaccurate modelling of the unit commitment and dispatch of CHP plants as well as the entire fuel consumption mix and resulting electricity prices. For example, the share of gas fired power plants in the electricity generation is underestimated, if the requirement to operate a large share of gas fired CHP plants to cover the given heat demand is neglected. This is for example the case in the Netherlands showing a high share of gas fired CHP plants.

In the following, the methodology applied to represent the operation of CHP plants in the market models is presented. Subsequently, data issues related to the modelling of CHP plants are discussed. Finally we describe in which the way CHP is treated in analysed countries.

6.4.2 Applied methodology to represent the operation of CHP plants

Within the European Electricity Market Model (E2M2s), the Joint Market Model (JMM) as well as the Scheduling Model (SM), the use of CHP plants to supply a given heat demand can explicitly be considered. CHP plants covered by the model can be distinguished into extraction condensing and backpressure units. Possible operation modes of these CHP plants are represented by simplified PQ-operation areas showing the possible operational combinations of electric P and thermal power Q produced. In Figure 9 examples of PQ-operation areas for the two different types of CHP turbines considered in the models are shown.

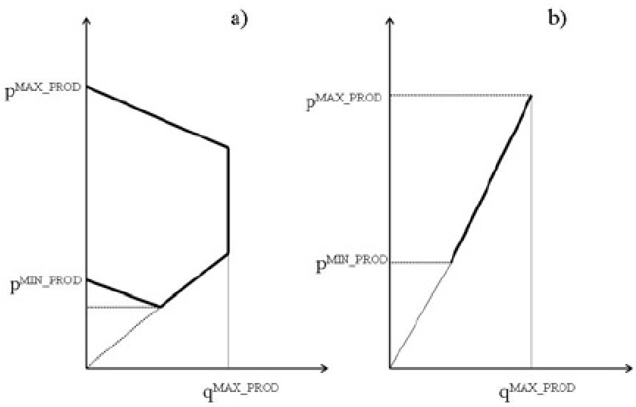

Figure 9. Simplified PQ-operation areas for a) extraction condensing turbines and b) backpressure turbines. Source: Meibom et al. (2007)

These technical restrictions are reflected by a set of model equations. Furthermore it is necessary to define heat regions to which CHP plants are then allocated. A detailed representation of CHP operation means a significant increase in computational effort due to additional model equations and high efforts on the data side as will be explained in the following section. The level of aggregation for modelling CHP operation is therefore a trade off between the potential improvement of modelling accuracy and additional efforts.

We apply the following procedure to reduce the computational effort by decreasing the number of considered district heating grids while simultaneously maintaining the required accuracy:

- Definition of major district heating networks that should be treated separately.
- Among those we identify district heating networks with a high share of gas fired CHP capacity.
- Aggregation of remaining CHP plants to cover the aggregated heat demand of one single artificial district heating region. This artificial district heating region will be dominated by coal and lignite fired CHP plants.

The application of this approach is exemplarily shown for Germany, compare Figure 10. In this example, the number of district heating grids considered has been reduced from approximately 240 to 21 (cf. AGFW (2007)). Even with this simplified representation the inclusion of CHP operation more than doubles the calculation time.

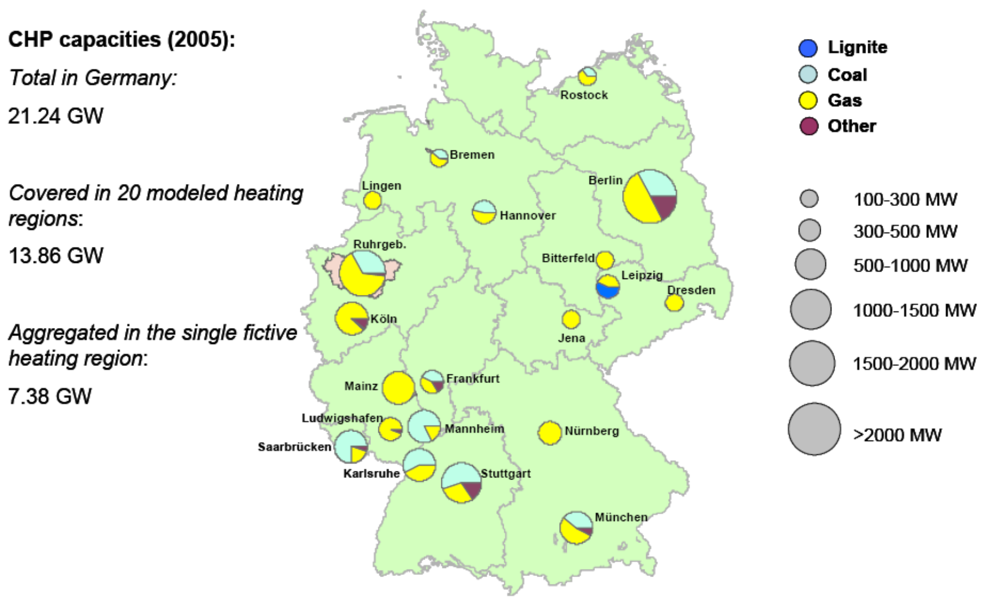

Figure 10. Exemplary representation of district heating grids in Germany

6.4.3 Data requirements

In order to model the operation of CHP plants, the following information is needed for each CHP plant:

- Supplied heating grid
- Type of the CHP technology (extraction condensing vs. backpressure)
- Heat capacity
- Power to heat ratio and power loss index due to heat generation

Furthermore, heat demand time-series of the modelled district heating grids are required. This data is in general not available. Therefore heat time series have to be modelled based on temperature data. If not available, heat capacities, power to heat ratio and power loss index are assumed based on typical parameters of the individual CHP technologies and the installed capacity.

6.4.4 Approach for CHP plant operation applied on country level

To reduce the effort of modelling and data collection, we consider CHP plant operation in detail only for selected countries which are characterised by a high current share of CHP and a significant share of comparable gas and oil fired CHP on total CHP generation. A detailed CHP representation is applied for Scandinavian countries, Austria, Germany and the Netherlands.

6.5 Grid representation

For model runs covering all analysed countries (EU27 +2, -2) grid constraints are reflected in form of NTC values published by ETSO. As there are no projections for NTC value available, these numbers are also used for the simulation of future scenarios. For case studies carried out in WP6 which aim at the identification of grid investments in specific regions the transmission grid is represented in detail using a full DC load flow model. Approach and assumptions for key line parameters (resistance, reactance, susceptance and thermal rating) are summarised in the corresponding work package report.

Acknowledgement

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